KNOWN: A gas expands from a specified initial state to a specified final pressure isothermally and without internal irreversibilities.

FIND: Determine the heat transfer and work per unit of mass, for (a) R134a, (b) Air as an ideal gas.

SCHEMATIC & GIVEN DATA:

\[ T = 333 \, \text{K (60^\circ \text{C})} \]

\[ P_1 = 14.6 \, \text{bar} \]

\[ P_2 = 2.8 \, \text{bar} \]

\[ V_1 = \text{?} \]

\[ V_2 = \text{?} \]

\[ \Delta T = \text{?} \]

\[ \Delta U = \text{?} \]

\[ \Delta W = \text{?} \]

\[ \Delta S = \text{?} \]

\[ \Delta Q = \text{?} \]

\[ \Delta H = \text{?} \]

\[ \Delta G = \text{?} \]

\[ \Delta A = \text{?} \]

\[ P_1 = 14.6 \, \text{bar} \]

\[ P_2 = 2.8 \, \text{bar} \]

\[ T_1 = \text{?} \]

\[ T_2 = \text{?} \]

\[ n = \text{?} \]

\[ m = \text{?} \]

\[ V_1 = \text{?} \]

\[ V_2 = \text{?} \]

\[ c_p = \text{?} \]

\[ c_v = \text{?} \]

\[ R = \text{?} \]

\[ c = \text{?} \]

\[ a = \text{?} \]

\[ b = \text{?} \]

\[ s = \text{?} \]

\[ h = \text{?} \]

\[ g = \text{?} \]

\[ A = \text{?} \]

\[ B = \text{?} \]

\[ \gamma = \text{?} \]

\[ \delta = \text{?} \]

\[ \alpha = \text{?} \]

\[ \beta = \text{?} \]

\[ \lambda = \text{?} \]

\[ \mu = \text{?} \]

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Water is the working fluid in a Carnot vapor power cycle. The states at the boiler and turbine inlets are specified and the condenser pressure is known. Determine (a) the thermal efficiency, (b) the back work ratio, (c) the heat transfer to the working fluid per unit mass passing through the boiler, and (d) the heat transfer from the working fluid passing through the condenser.

**KNOWLEDGE:**

1. Each component is analyzed as a control volume at steady state.
2. All processes of the working fluid are internally reversible.
3. The turbine and the pump operate adiabatically.
4. Kinetic and potential energy effects are negligible.

**ENGINEERING:**

1. Each component is analyzed as a control volume at steady state. (2) All processes of the working fluid are internally reversible. (3) The turbine and the pump operate adiabatically. (4) Kinetic and potential energy effects are negligible.

**ANALYSIS:**

First, fix each of the principal states:

State 1: $p_1 = 100 \text{ bar}$, sat. vapor $\Rightarrow h_1 = 2729.7 \text{ kJ/kg}$, $s_1 = 5.664 \text{ kJ/kg-K}$

State 2: $P_2 = 0.06 \text{ bar}$, $S_2 = S_1 \Rightarrow \frac{S_2 - S_1}{S_1} = 0.0522 \Rightarrow h_2 = 1727.2 \text{ kJ/kg}$

State 3: $p_3 = 0.06 \text{ bar}$, $S_3 = S_4 = 3.3546 \text{ kJ/kg-K}$ $\Rightarrow \frac{S_3 - S_2}{S_2 - S_1} = 0.3635 \Rightarrow h_3 = 1029.7 \text{ kJ/kg}$

State 4: $p_4 = 100 \text{ bar}$, sat. liquid $\Rightarrow h_4 = 1407.6 \text{ kJ/kg}$

(a) The thermal efficiency of the Carnot cycle is given by Eq. 5.9. With data from Table A-3: $T_h = TSat@100 \text{ bar} = 584.23 \text{ K}$ and $T_c = TSat@0.06 \text{ bar} = 309.31 \text{ K}$. Thus,

\[ \eta = \frac{T_h - T_c}{T_h} = \frac{309.31 \text{ K}}{584.23 \text{ K}} = 0.4706 (47.06\%) \]

(b) The back work ratio is

\[ \frac{W_{br}}{W_{el}} = \frac{h_4 - h_3}{h_1 - h_2} = \frac{1407.6 - 1029.7}{2729.7 - 1727.2} = 0.3768 \]

(c) For the boiler: $\dot{Q}/\dot{m} = h_1 - h_2 = 2729.7 - 1407.6 = 1317.1 \text{ kJ/}\dot{m}$

(d) For the condenser: $\dot{Q}/\dot{m} = h_4 - h_3 = 1727.2 - 1029.7 = 697.5 \text{ kJ/}\dot{m}$

1. Alternatively, $\eta = \frac{W_{el}}{\dot{Q}/\dot{m}} = \frac{1 - 697.5}{1317.1} = 0.4704$

2. These results allow comparison of the Carnot cycle with the corresponding ideal Rankine cycle of Problem 8.1.